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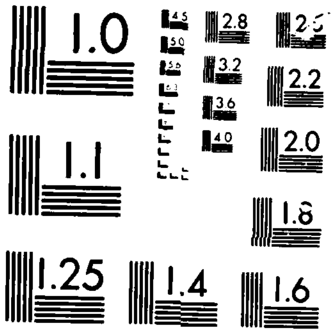

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1 July 1985 through 30 June 1986

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MATRIX THEORY

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From: Henryk Minc, Principal Investigator,
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To: Richard D. Ringeisen,
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Subj.: ONR Contract N00014-85-K-0489.
Annual Report, 1 July 1985 - 30 June 1986.

Dear Dr. Ringeisen,

My research activity during the past year concerned permanents of (0,1)-circulants. ~~In [1]~~ I developed a method for constructing a recurrence formula for expressing the permanent of any (0,1)-circulant in terms of permanents of (0,1)-circulants of the same type of lower orders. This paper was actually written before the starting date of my ONR contract, but it was revised in July 1985, and thus the work was supported in part by the ONR. An acknowledgment to this effect was added in proof but it was inadvertently omitted by the printer.

It was shown in [1] that a recurrence relation for the permanent of an $n \times n$ (0,1)-circulant

$$A_n = I_n + P^{t_2} + P^{t_3} + \dots + P^{t_{k-1}} + P^{t_k}, \qquad (1)$$

$1 \leq t_2 < t_3 < \dots < t_k < n$, can be generated from the product of

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permanental compounds of the companion matrix of the *associated polynomial*

$$\lambda^{t} - \lambda^{t-t_2} - \lambda^{t-t_3} - \dots - \lambda^{t-t_{k-1}} - 1, \qquad (2)$$

where $t = t_k$. Unfortunately, the characteristic polynomials of permanental compounds cannot be constructed by a direct method except for small values of t. In [2] I posed the problem of finding an efficient algorithm for determining the characteristic polynomial of the rth permanental compound of a given matrix. The problem is unsolved, and it seems to be very difficult.

Even if a recurrence formula can be constructed for a certain type of (0,1)-circulants, it may still be impossible to use it for the purpose of evaluation of permanents, since a recurrence formula cannot be used until the initial values have been computed, and these cannot be evaluated for $t \geqslant 5$ by any known method. For larger values for t, the most that can be hoped for is the evaluation of the asymptotic function

$$\theta\langle z\rangle = \lim_{n\to\infty} \operatorname{per}(A_n\langle z\rangle)^{1/n},$$

where $\langle z\rangle$ designates the *type* of the circulant, determined by exponents $t_2, t_3, \dots, t_{k-1}, t$, in (1). I showed in [1] that $\theta\langle z\rangle$ is equal to the largest of the Perron roots of the permanental compounds of the companion matrix of the associated polynomial (2). The second problem posed in paper [2] asks for an algorithm which would evaluate the Perron root of a permanental compound of a nonnegative matrix. This problem is also unsolved.

Paper [3], which extends to 32 printed pages and represents the major part of the work performed during the past year, is a study of properties of permanental compounds of companion matrices and their application to the problem of evaluating the asymptotic permanental function $\theta\langle z\rangle$. I obtained necessary and sufficient conditions for a companion matrix to be convertible (a real $t \times t$ matrix A is said to be *convertible* if there exists a real matrix B such that $|A| = |B|$, and the rth permanental compound of A is equal to the rth (determinantal) compound of B, $r = 2, 3, \ldots, t-1$). I also derived formulas for (0,1)-circulants whose associated polynomials have convertible companion matrices, expressing $\theta\langle z\rangle$ in terms of roots of the associated polynomials. I made use of the *root-squaring method* to compute a range of values of $\theta\langle z\rangle$ for (0,1)-circulants of the above type. The paper concludes with a discussion of two possible applications for the function $\theta\langle z\rangle$.

I plan to present the results obtained in [1] and [3] at the International Congress of Mathematicians in Berkeley.

Paper [4] is a quadrennial survey of the progress in the theory of permanents. This project is a sequel to my treatise *Permanents* and my survey paper *Theory of Permanents 1978-1981*. A search of the literature has now been completed, and 83 papers on permanents, published in 1982-1985, have been identified. Additional 31 items published prior to 1982, but not included in previous bibliographies, will be also listed in [4]. The paper

will contain a short abstract of each paper. I plan to complete this work by the end of July.

Item [5] is an advanced book on which I have been working for several years. Two further chapters representing about a quarter of the work are still to be written. I do not plan to do any work on this project during the summer research activity period.

Yours sincerely,

Henryk Minc

Encl.: Publication List

CC: Administrative Contracting Officer (1)

Director, Naval Research Laboratory (6)

Defense Technical Information Center (12)

HENRYK MINC

PUBLICATIONS

completed under ONR Research Contract N00014-85-K-0489

1 July 1985 - 30 June 1986

[1] Recurrence formulas for permanents of (0,1)-circulants, *Linear Algebra Appl.* **80** (1985), 241-265.

[2] Research Problems: Permanental Compounds, *Linear and Multilinear Algebra* **19** (1986), 199-201.

[3] Permanental compounds of companion matrices and (0,1)-circulants, *Linear Algebra Appl.* (to appear in 1986).

In preparation

[4] Theory of permanents 1982-1985.

[5] *Nonnegative Matrices* (to be published by John Wiley & Son).

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